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HIP FRACTURES IN ADULTS

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REVIEW ARTICLE

Risk Stratification in Hip Fractures

Abstract

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Hip fractures are often the consequence of low energy trauma, especially in the elderly with osteoporosis. The incidence is rising globally because of secular increase in the prevalence of osteoporosis. This article explores the key risk factors and stratification tools for hip fractures, aiming to equip clinicians with evidence-based insights to improve patient outcomes. Effective risk stratification is pivotal for optimizing patient outcomes, enabling early identification of high-risk individuals, facilitating multidisciplinary interventions, and guiding resource allocation to mitigate mortality, morbidity, and healthcare burdens. The array of validated tools from FRAX and QFracture for predicting fracture occurrence to Nottingham Hip Fracture Score, Almelo Hip Fracture Score, and others for postoperative prognosis provides clinicians with evidence-based frameworks. Thus, a comprehensive approach combining thorough risk factor evaluation with appropriate stratification tools empowers healthcare providers to deliver targeted interventions, improve survival rates, and enhance quality of life for patients with hip fractures. Continued research and global calibration of these instruments will further refine their utility in addressing this escalating epidemic.

KEYWORDS

Hip Fractures; Risk Assessment; Osteoporotic Fractures; Bone Density; Accidental Falls; Comorbidity; Mortality; Frailty

Introduction

Hip fractures are often the consequence of low energy trauma, especially in the elderly with osteoporosis.[1] The incidence is rising globally because of secular increase in the prevalence of osteoporosis.[2] The global incidence is around 681 per 100000 population with increasing trend in the elderly.[3] The incidence is predicted to be around 20 million by the year 2050 and in Asia, the overall incidence of hip fracture could be increased by 40%.[4] These fractures are often considered significant public health burden because of their association with increased mortality, morbidity, and health care costs.[3] Management of these fractures is also challenging because of heterogenous outcomes, as some patients respond well to treatment whereas others do not.[5] Several factors, such as advanced age and preexisting conditions such as chronic obstructive pulmonary diseases, heart failure or chronic kidney disease, contributes to the poor prognosis.[6] Thus, risk stratification is essential to optimize perioperative care and tailor interventions in order to obtain optimal results.

Risk stratification refers to the systematic assessment of patient-specific factors to predict adverse clinical outcomes.[7,8] It is crucial

because hip fractures involve multifaceted geriatric syndromes influenced by comorbidities, functional status, and physiological reserve.[7] Effective stratification allows clinicians to identify high-risk patients which can prompt early involvement of multidisciplinary teams, including geriatricians, anesthesiologists, and intensivists, to mitigate complications like delirium and cardiovascular events.[8] Historically, risk assessment in hip fractures relied mainly on clinical judgment and basic parameters like age, gender, and American Society of Anesthesiologists (ASA) scores.[7] However, more sophisticated stratification tools have been developed over the years incorporating multiple variables.[8] These tools not only predict mortality but also guide preventive strategies, treatment planning, post-operative rehabilitation and discharge planning and allocation of healthcare resources.[8] Thus, this article explores the key risk factors and stratification tools for hip fractures, aiming to equip clinicians with evidence-based insights to improve patient outcomes.

Risk Factors for Hip Fracture

Risk factors for hip fracture are often multifactorial and include both modifiable and non-modifiable factors.[9] (Table 1)

Table 1. Risk factors for hip fractures

A.	**Non-modifiable factors**
a.	Age >70 years
b.	Female Gender
c.	Caucasian race
d.	History of previous fracture
e.	Parental history of hip fracture
F.	**Modifiable risk factors**
a.	Fall
b.	Low bone mineral density (BMD)
c.	Frailty
d.	Sarcopenia
e.	Inactivity or lack of exercise
f.	Smoking
g.	Excessive alcohol intake
h.	Medical co-morbidities
i.	Environmental factors
j.	Medication (anxiolytics, proton-pump inhibitors, loop diuretics, benzodiazepines, levothyroxine, and corticosteroids etc.)
k.	Vitamin d deficiency
l.	Cognitive impairment
m.	Impaired vision and perception

Age, Gender, and Race

Age is probably the strongest risk factor for hip fracture.[10] A multi-center study conducted in United Kingdom found that post-menopausal women have twice the higher risk of having hip fractures than pre-menopausal women.[10] The study also found that the incidence of hip fracture increases with increase in age with 7-time higher risk at the age of 70-74 years.[10] Their findings highlighted that age was strong contributor than menopause.[10] Classical characteristics of aging include reduced sex-hormone levels, unhealthy life-style practices, muscle weakness, and presence of co-morbidities. However, these characteristics were not specific to reduction in bone health resulting in the occurrence of hip fractures.[11] Thus, Buzkova and colleagues, in their review, evaluated biological characteristics of aging that increases the risk of hip fracture and found five important characteristics that increases the risk of hip fractures by 10-25%.[11] The five characteristics of aging are: 1) microvascular diseases of kidney and brain; 2) reduced parasympathetic tone; 3) increased carboxymethyl-lysin levels; 4) carotid artery atherosclerosis; and 5) increase trans-fatty acid levels.[11]

Female gender has higher risk of having hip fracture than males because of low bone mineral density (BMD) among females.[12] A study conducted in Japan including 17,395 patients with hip fracture found that around 80% were females.[13] Most studies agree that female gender is an independent age-adjusted risk factor for hip fractures in the elderly.[9,12–14]

Caucasian or white race has been found to have higher hip fracture risk than Africans and Asians.[15] The reason behind that is higher prevalence of osteoporosis among Caucasians. A

study conducted in United States observed that the incidence of hip fracture was significantly (>50%) lower among United States Asian and Pacific Islanders compared to that of Non-Hispanic Whites.[16] Among United States Asians, Chinese women had higher adjusted hazard ratio for hip fracture based on reduction in T-score followed by Japanese women and south Asian women.[17]

Prior history of fracture

History of previous fracture is also an independent risk factor irrespective of gender and even low BMD.[18] A meta-analysis involving 64 cohorts from all around the globe found that individuals with prior history of fracture had significantly higher risk of any clinical fractures, major osteoporotic fracture and hip fractures compared to those without the history of fracture with risk ratio or 1.82-1.87.[18] Another study evaluated whether the time elapsed from previous fracture have impact over the risk of having subsequent fracture and found that the "time to first validated fracture" is not an independent risk factor for subsequent fracture.[19] They suggested that patient with a first episode of fragility fracture should be considered a high risk of subsequent fracture irrespective of time elapsed.[19]

Parental history of hip fracture

Fragility fractures are known to have high heritability. Fox and colleagues (1998) investigated parental history of hip fracture as a risk factor and found that positive family history is an important risk factor.[20] Among 7963 women with age more than 65 years, fractures occurred during an average of 7.1 years of follow-up and the risk of hip fracture increased significantly among those who had history of maternal (1.48; 95% CI = 1.03-2.11) history of hip fractures as well as sister's (1.83; 1.20-2.80) or brother's history of hip fracture (2.26; 1.16-4.42).[20] For wrist fracture the risk was increased with history of maternal and paternal writs fractures.[20] However, they also found that the history of parental hip fracture as a risk factor is site specific, as having history of wrist fracture did not increase the risk of hip fracture and vice versa.[20] Two meta-analyses in different time frame investigated the association of family history of fracture and fracture risks and drew the same conclusion that family history of fracture is a strong risk factor for fragility fracture which is independent of low BMD and parental history of hip fracture is the strongest predictor for hip fractures with hazard ratio and risk ratio of 1.15 and 2.27, respectively.[21,22]This suggests that although parental history of fracture can be considered a risk factor for any site-specific fragility fracture, parental history of hip fracture is certainly an important risk factor for hip fracture.

Fall

History of fall has been commonly associated with fragility fractures. It remains a major preventable risk factor.[12] A real-world evidence study suggested that each episode of fall increased the risk of hip fracture by 1.7 times.[12] Analysis of data obtained from Study of Osteoporotic Fractures (SOF) and Osteoporotic Fractures in Men Study (MrOS) showed that recent falls within 4 months leads to higher hip and non-spine fractures.[23] Absolute risk increases by 2.5% for hip fractures and 8.1% for non-spine fractures in the following year in both sexes.[23] However, some authors have argued that fall is not an independent risk factor for hip fracture, as it is often multifactorial.[24–26]

Low BMD, frailty, older age, sarcopenia, impaired vision and perception, and co-morbidities, such as diabetes mellitus and chronic obstructive pulmonary disease (COPD), often contributes heavily to fall related hip fractures. Lim et al., in their cross-sectional study, found that sarcopenia is an independent risk factor for fragile falls.[27] Similarly, both moderate and severe comorbidities according to Charlson comorbidity index poses strong risk for fragility falls and subsequent hip fractures with odds ratio of 3.57 (95% CI 1.10-11.50) and 5.396 (95% CI 1.476-19.729), respectfully.[27]

Low BMD

Low BMD is one of the important risk factors for hip fractures.[15] Data from EPIDOS prospective study and their subgroup analyses suggested that women with low BMD has double the higher risk of having hip fractures than women with normal BMD of same age.[28] Similarly, Cornwell Hip Fracture study also found that low BMD is a strong risk factor for hip fracture among post-menopausal women compared to other anthropometric measurements of proximal femur.[29]

It is also known that there is high prevalence of hip and spine BMD discordance, i.e. different state of osteoporosis in different location, among patients with osteoporosis.[30,31] Although low BMD at all regions, including vertebrae, femoral neck, hip, and calcaneus, contributes to hip fractures, femoral neck BMD had been found to be two-time stronger predictor for hip fractures.[17,32] Similarly, another study found that within the threshold defined by world health organization (WHO), hip fracture incidence was around 3- and 4-times higher in patients with BMD discordance and low hip discordance. This suggests that low BMD, especially femoral neck BMD, is a strong risk factor for hip fractures. However, low BMD is often associated with several other risk factors, such as higher age, smoking, multiple comorbidities, drug use, sarcopenia and frailty, in resulting in higher incidence of hip fractures.[33–39] A case-control study highlighted that patients with low BMD, smoking, and multiple co-morbidities have significantly higher risk of having hip fracture compared to age- and gender-matched controls.[40]

Risk Stratification Tools

Risk stratification tools can broadly be divided into two categories: 1) for prediction of hip fracture risk and 2) for prediction of clinical outcomes. (Table 2)

Table 2. Risk Stratification Tools

A. For predicting hip fracture risk	
a. FRAX (Fracture risk assessment tool)	https://www.fraxplus.org/calculation-tool/
b. QFracture	https://qfracture.org/
c. Garvan Fracture Risk Calculator	https://fractureriskcalculator.com.au/calculator/
d. CAROC (Canadian Association of Radiologists and Osteoporosis Canada)	https://osteoporosis.ca/caroc/
e. Fall risk assessments	https://pmc.ncbi.nlm.nih.gov/articles/PMC8608097/
f. BMD measurements	
G. For Predicting clinical outcomes	
a. Nottingham Hip Fracture Score	https://thereisafracture.co.uk/NHFS/index.htm
b. Almelo Hip Fracture Score	https://www.evidencio.com/models/show/1047?v=1.11
c. Rotterdam Hip Fracture Mortality Prediction-30 Da ys	https://www.mdcalc.com/calc/10616/rotterdam-hip-fracture-mortality-prediction-30-days-rhmp-30
d. Orthopedic POSSUM	https://www.medcentral.com/calculators/orthopedics/possum-score-for-orthopedic-procedure-prognosis
e. Charlson Comorbidity Index	https://orthotoolkit.com/charlson-comorbidity-index/
f. American Society of Anesthesiologist (ASA) classification	https://www.asahq.org/standards-and-practice-parameters/statement-on-asa-physical-status-classification-system
g. ACS-NSQIP Surgical Risk Calculator	https://riskcalculator.facs.org/RiskCalculator/

BMD Bone Mineral Density; *POSSUM* Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity; *ACS-NSQIP* American College of Surgeons National Surgical Quality Improvement Program

Tools for predicting hip fracture risk

a. FRAX (fracture risk assessment tool)

FRAX (https://www.fraxplus.org/calculation-tool/) is a tool designed to predict the 10-year probability of a major osteoporotic fractures (MOFs) and hip fractures.[41] Initially, osteoporosis treatment decisions were only based on BMD measurements obtained via Dual-energy X-ray Absorptiometry (DXA) scans.[42] The WHO defined osteoporosis as a T-score of -2.5 or lower.[43] However, several studies revealed that the most fragility fractures occurred in individuals not in the "osteoporosis" range.[7,44] This highlighted that low BMD alone was an insufficient predictor of fragility fracture risk. Several validated clinical risk factors (CRFs) have been described in the literature.[45] Thus, FRAX was developed to integrate CRFs with or without BMD in predicting fracture risks.[41]

Validated CRFs

1. Age
2. Sex
3. Weight and Height (BMI)
4. Previous Fracture
5. Parental Hip Fracture
6. Current Smoking
7. Glucocorticoids
8. Rheumatoid Arthritis
9. Secondary Osteoporosis
10. Alcohol Intake

National Osteoporosis Guideline Group (NOGG) and National Osteoporosis Foundation (NOF) guidelines provide the treatment "thresholds" based on FRAX scores as: Low Risk: Reassurance, lifestyle modification and supplements; Intermediate Risk: Measure BMD to refine the risk score and treat accordingly; High Risk: Consider pharmacological treatment (oral or parenteral).[46] This treatment mechanism often ensures well targeted treatment to the individuals who

actually require the treatment (i.e. individuals with validated CRFs and low BMD) rather than blanketing treatment for everyone with just a low BMD as determined by the T-score values.[41,46] FRAX assessment tool has several advantages. It ensures more holistic assessment as various validated CRFs are taken into account.[18,22,41] It is user friendly and cost-effective fracture assessment modal and has strong prospect of global calibration and world-wide accessibility.[41,44] However, it is not devoid of fallacies, which are highlighted below:

1. Dichotomous Input:
Most variables use "Yes/No" inputs. The FRAX model does not consider the dose, severity, or duration, which may substantially increase the overall fracture risks. Some examples: A patient smoking 30 cigarettes a day for 12 years has the same "Yes" input for smoking as someone smoking 1 cigarette a day for 6 months, and a patient with 3 prior fractures has the same "Yes" input for history of previous fractures as a patient with 1 prior fracture.

2. Falls Risk:
FRAX does not explicitly include a history of falls as an input variable, despite falls being the immediate cause of most fractures. This is a major criticism, though the authors argue that falls risk is implicitly captured in prior fracture history.

3. Lumbar Spine BMD:
FRAX uses only the Femoral Neck BMD. It does not accommodate Lumbar Spine BMD, which can sometimes be much lower than the hip (discordance), potentially leading to an underestimation of risk in patients with spinal osteoporosis.

4. Type 2 Diabetes:
FRAX also underestimates risk in patients with Type 2 Diabetes, which is considered a valid risk factor.

5. Underestimation in Recent Fractures:
The risk of a second fracture is highest immediately after the first (imminent risk). FRAX calculates a 10-year average and may underestimate the acute risk in the first 1-2 years following a sentinel event.

b. QFracture

The QFracture tool (www.qfracture.org) also consider the history of smoking, alcohol, corticosteroid use, parental history (of hip fracture or osteoporosis) and several secondary causes of osteoporosis as risk factors.[47] It is based on a study conducted in UK among osteoporotic men and women of age 30-85years.[48] Although FRAX model is widely preferred, QFracture has some advantages over FRAX.[49] Other than risk factors considered in FRAX, QFracture also includes a history of falls, utilizes a large number of clinical risk factors and no provision is made for BMD. It has been well validated both internally and externally validated.[48] The performance characteristics and calibration in the UK have been compared with FRAX with comparable results for hip fracture.[48,49] However, this tool also has some limitations, such as it is not calibrated to the population of other countries and it is difficult to use and more cumbersome. In addition, the tool dismisses BMD measurements citing it as "expensive and inconvenient" thereby ignoring a wealth of data supporting the utility of BMD testing in predicting fracture risks.[47]

c. Garvan Fracture Risk Calculator

The Garvan tool (www.garvan.org.au) is based on a single study conducted in Australia, the Australian Dubbo Osteoporosis Epidemiology Study (DOES), including sample size of only 2500 men and women of age ≥60 years.[47] Unlike FRAX model, it includes several categorized variables in an attempt to counter the limitation of FRAX model.[47] Some examples include history of falls categorized as 0, 1, 2, >2 in the previous year, and the number of previous fragility fractures categorized as 0, 1, 2, >2. However, this tool does not consider other FRAX risk factors such as smoking, alcohol intake, parental history of hip fracture, secondary osteoporosis, rheumatoid arthritis, and glucocorticoid use.[47]

d. CAROC

Canadian Association of Radiologists and Osteoporosis Canada (CAROC) is an alternative tool used in Canada.[50] Like FRAX model, the CAROC considers age, gender, and BMD results, but does not consider risk factors like family history.[50,51] CAROC also produces categorical assessments of risks as Low, Moderate and High.[51] Literature suggests that the prediction assessment matches with the FRAX model around 89% of the time, suggesting its effectiveness in fracture risk assessments.[50–52] The guidelines in Canada favored FRAX tool than CAROC and recommended to use it as an alternative.[52]

e. Fall Risk Assessment Tool

A systematic review identified a total of 38 fall risk assessment tools in the literature.[53] Out of 38, 23 target hospitalized patients, 8 are used for home residents, and 7 for both.[53] Because the risk of falling is multifaceted, there isn't a single "ideal" method that works in every situation or does a flawless risk assessment.[53,54] A direct and thorough analysis by the healthcare professional is crucial, and the simultaneous use of multiple tools is often recommended.[53,54]

Tools for Predicting outcomes

a. Nottingham Hip Fracture Score

The NHFS is a British risk scoring system designed to predict 30-day mortality in patients with hip fractures.[55] Age, sex, cancer, dementia, preoperative living condition, hemoglobin levels, and predetermined comorbidities are the objective indicators that are used.[55] Cerebrovascular, cardiovascular, renal, and respiratory disorders are among

the predefined comorbidities. It can be used as a screening approach prior to the anesthetic assessment because it is computed based on the patient's history upon admission. Patients' preoperative physical conditions can be reflected in this scoring system, and all variables can be gathered from their routine examination and medical history at admission. Small subjectivity, fewer items, easy collection, and straightforward computation are its defining characteristics.[55]

It is widely validated tool and has demonstrated the ability to accurately predict the 30-day mortality after surgery, especially in elderly patients with hip fractures.[55–58]

b. Almelo Hip Fracture Score

The Almelo Hip Fracture Score (AHFS) is a clinical instrument that uses nine basic preoperative characteristics, such as age, sex, dementia, and hemoglobin, to predict the probability of early death (within 30 days) for patients 70 years of age or older who undergo hip fracture surgery.[59] It shows better prediction than some other ratings and helps surgeons personalize care for fragile elderly patients by classifying patients into low (≤9), medium (10–12), and high (≥13) risk groups.

c. Rotterdam Hip Fracture Mortality Prediction-30 Days

The Rotterdam Hip Fracture Mortality Prediction-30 Days (RHMP-30) is a validated clinical tool that provides a quantitative risk assessment to support shared decision-making by estimating a patient's 30-day risk of death following hip fracture surgery based on variables such as age, gender, ASA score, dementia, albumin, Katz ADL score, and nursing home residence.[60] In a study including 3523 patients, the prediction model's area under the receiver operating characteristic curve for both the training and testing cohorts was 0.789 and 0.775, respectively, and the calibration curve demonstrated a strong correlation between the expected and observed 30-day mortality.[60]

d. Orthopedic POSSUM

Orthopedic POSSUM (O-POSSUM) is a specific adaptation of the original Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity (POSSUM) scoring system used in orthopedic and trauma surgery to predict a patient's risk of morbidity and mortality from surgery.[61] It combines patient's physiological status (like age, heart rate, blood tests) with operative factors (like surgical complexity, blood loss) to allow for accurate assessments of surgical outcomes.[62,63] It is often useful for auditing and assessing patients risk following hip fracture surgery.

e. Charlson Comorbidity Index

The Charlson Comorbidity Index (CCI) is a popular tool that rates a patient's overall health by adding points for age and assigning points to 19 specific chronic diseases (such as cancer, diabetes, and heart failure).[64] It was developed to predict one-year survival.[64] For use in longitudinal research, this tool offers a straightforward, practical, and reliable way to estimate the risk of death from comorbid disease.[64] It is well validated and widely used.[65] Higher scores indicate greater comorbidity burden and increased risk of mortality or resource use.[64,65]

Conclusion

In conclusion, hip fractures represent a growing public health challenge, particularly in aging populations, driven by multifactorial risks ranging from non-modifiable factors like advanced age, female gender, and genetic predisposition to modifiable elements such as falls, low bone

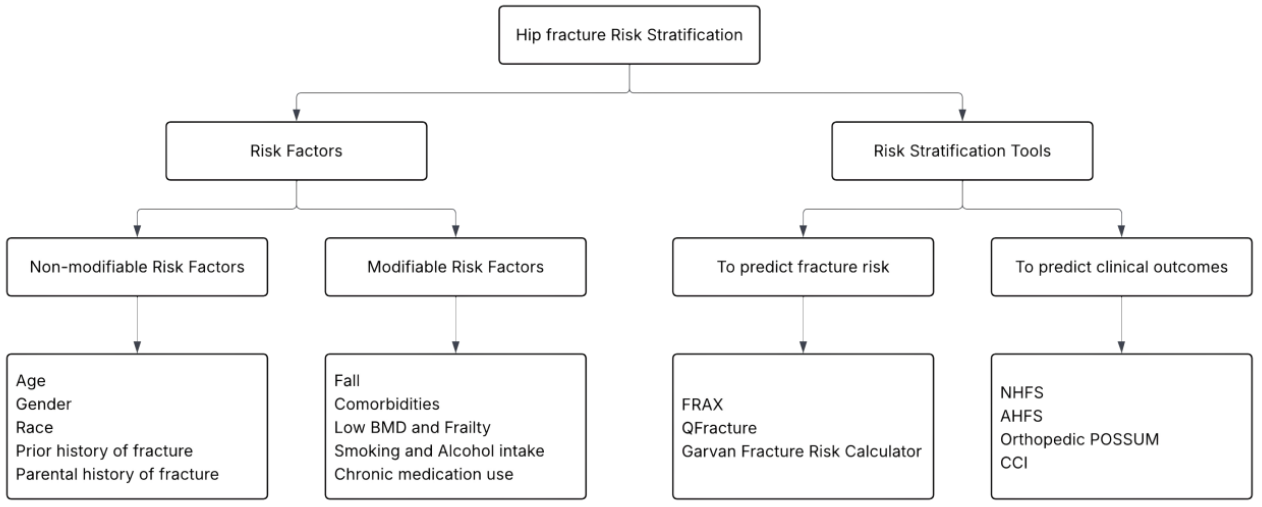

Figure 1 Summary Algorithm of Hip Fracture Risk Assessment

mineral density, frailty, and lifestyle behaviors. Effective risk stratification is pivotal for optimizing patient outcomes, enabling early identification of high-risk individuals, facilitating multidisciplinary interventions, and guiding resource allocation to mitigate mortality, morbidity, and healthcare burdens. (Figure 1) The array of validated tools from FRAX and QFracture for predicting fracture occurrence to Nottingham Hip Fracture Score, Almelo Hip Fracture Score, and others for postoperative prognosis provides clinicians with evidence-based frameworks. While each tool has strengths and limitations, their integration into clinical practice enhances preventive strategies, treatment decisions, rehabilitation planning, and shared decision-making.

Thus, a comprehensive approach combining thorough risk factor evaluation with appropriate stratification tools empowers healthcare providers to deliver targeted interventions, improve survival rates, and enhance quality of life for patients with hip fractures. Continued research and global calibration of these instruments will further refine their utility in addressing this escalating epidemic.

Conflict of Interest

None

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